DIY low voltage alarm

Willem Bijl designs and builds a battery monitor

David Harding/PBO

Force 4, towards the river bank and backing, my anchor was dragging, battery failure, not enough power for a manual start. I only needed one strong man aboard to help start the engine.

Their immediate response was to call the RNLI's West Mersea lifeboat. It was a very embarrassing feeling. Depth 0.3m.

The coastguard asked for some more information and just after 0300 informed me that the lifeboat had been launched.

I answered the lifeboat's piercing searchlight with my torch. Their arrival at 0325 with the B Class Inshore Lifeboat looked just like the many photos in the RNLI magazine. They positioned themselves to the lee side and one man came on board. I welcomed him and the three other crew who stayed in the lifeboat. We chatted that this was easier than in a storm in a rough sea.

The lifeboatman started my engine with the first attempt. Depth was now 1.6m, so the anchor had held at last and the tide was rising. While I steered towards deeper water, my RNLI crew member weighed the anchor and the automatic nav lights had come on again. We were escorted home by the lifeboat and at 0403 berthed in Maylandsea. Thank you RNLI!

Sight and sound

The next afternoon I went to look for my hearing aid at low water and surprise, surprise, there it lay next to the bow on the mud! I washed it under the freshwater tap and at home later found out how to open it. After several washes with increasing proportions of methylated spirits and a good blow dry – the next day it was working again.

With regard to my misadventure detailed on the previous pages, in retrospect it should have been possible to prevent that outcome by simply having an alarm that would warn me of a dying battery before it was dead and too late to start the engine.

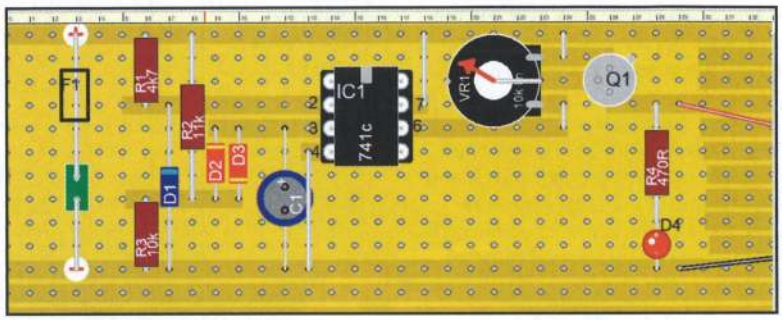
The minimum level of acceptable discharge is 11.5V. That would be the limit to start the engine and get the battery recharged.

The easiest solution would be to get a second battery dedicated to engine starting, but sadly there's no space for that in my yacht *Flotaxe*.

So I set out to design a low-voltage alarm connected to the onboard 12V system that would warn me the very moment that the voltage dropped below 11.6V, and then cut out once the voltage has increased again.

It may look daunting to the uninitiated, but that shouldn't stop anyone from copying it and building it as a kit.

It's actually very simple with just a few components – and it works!



Circuit Wizard Standard Demo

This digital rendering of the circuit on a Vero board shows the enhanced design of the alarm. Note: the optional reverse polarity guard is not included. The render differs from the diagrams over the page – the battery terminals are to the left here; to the right on the diagrams. And the buzzer is off the page to the right.

DESIGN BRIEF AND COMPONENTS

A brief description of the minimal performance requirements:

- a non-stable power supply
- simple design, no relays
- an alarm that would switch to 'on' like a 'flip-flop' rather than turning on slowly.
- Low current in the 'off' position
- Common available parts

Design requirements:

- Vs (the +ve supply voltage) is both the power supply of the unit and at the same time the voltage being sensed.
- With a Vs of 11.6V or higher the alarm must be 'off'.
- When Vs drops to 11.5V or lower, the alarm must be 'on'.
- Calculations are done using an 11.5V supply as that is the critical minimal +ve voltage.
- A prototype was made first.

Components list:

- Vero Board, Mounting box
- R1 - 4.7k resistor
- R2 - 11k resistor. This value determines the level of the critical switching voltage of Vs at 11.5V. Other resistor values of R2 will create different critical supply voltages. Instead of R2 a choice of resistors can be connected from R3 to Vs through a multi-position switch for different critical voltage choices.
- R3 - 10k resistor
- R4 - 470R resistor
- D1 - Zener diode (500mW, 5.6V)
- D2 & D3 diodes (Schottky 0.4V, 110V, 750mA)
- D4 - LED 3mm, red
- C1 - electrolytic capacitor (35µF, 25V)
- F1 - fuse-S 250mA (in + line)
- IC1 - op-amp 741c (DIL8)
- VR1 - 10k lin preset potentiometer
- Q1 - transistor (PNP, 2SB171 or BC557 or other*)
- BZ1 - buzzer 12V

Not displayed on diagram:

- D5 - Optional 1A diode rectifier for reverse polarity safety between the battery connections + and – in reverse position, ie non-conducting. The marking ring is connected to + but not in the power supply line!

Basic version

A stable reference voltage is created with a Zener diode (D1) of a nominal value of 5.6V with a resistor (R1) of 4700Ω [4.7k Ohms] in series.

The resulting current is only 1.2mA which causes the Zener voltage to be slightly lower, around 5.5V.

This stabilised voltage goes to the inverting input (pin 2) of the op-amp 741 (IC1 on the diagram).

Simultaneously the voltage divider R2 and R3 creates a 'comparison' voltage, which is measured at the non-inverting input (pin 3) of IC1.

As long as the supply voltage is still 11.6V (or higher), the voltage between R2 and R3 is above 5.52V so the alarm is 'off'.

When the voltage of R2/R3 drops to 5.48V this is lower than the reference voltage of 5.5V so IC1 flips over and the alarm goes 'on' (via pin 6). Note: pins 7 & 4 supply the operating power to IC1.

Flawed design

When my prototype was finished it had the disadvantage of 'jittering' or 'chirping' a weak sound of the buzzer when the critical voltage was approached due to its sensitivity – it responds to variations of 0.01V.

Enhanced version

I altered the design so that once a triggering low voltage is reached, however brief, the alarm must stay 'on' until the voltage has increased by at least 0.8V, an increase that could be caused by the engine being switched on (recharging) or by me switching something off (reducing current demand).

I introduced hysteresis (laziness) by inserting a capacitor (C1) and two Schottky diodes (D2 & D3).

These diodes (D2 & D3) have a voltage drop of about 0.4V when a current passes.

This current charges capacitor C1.

The 2 diodes are parallel and in opposition.

When the main boat electricity is switched on, supply voltage goes through R2 and D2 and charges C1 positive.

Components list:

- F1 - fuse
- R1 - 4.7k resistor
- D1 - Zener diode (500mW, 5.6V)
- R2 - 11k resistor.
- R3 - 10k resistor
- IC1 - op-amp 741c (DIL8)
- VR1 - 10k lin preset potentiometer
- Q1 - transistor (PNP, 2SB171 or BC557 or other*)
- R4 - 470R resistor
- D4 - LED 3mm, red
- BZ1 - buzzer 12V

- D2 & D3 diodes (Schottky 0.4V, 110V, 750mA)
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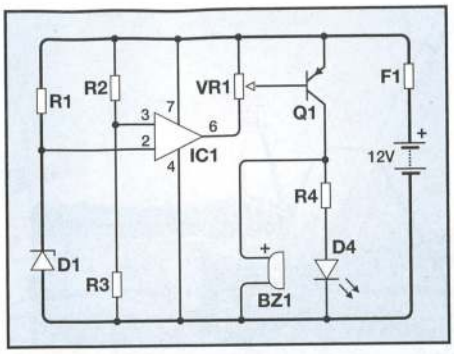
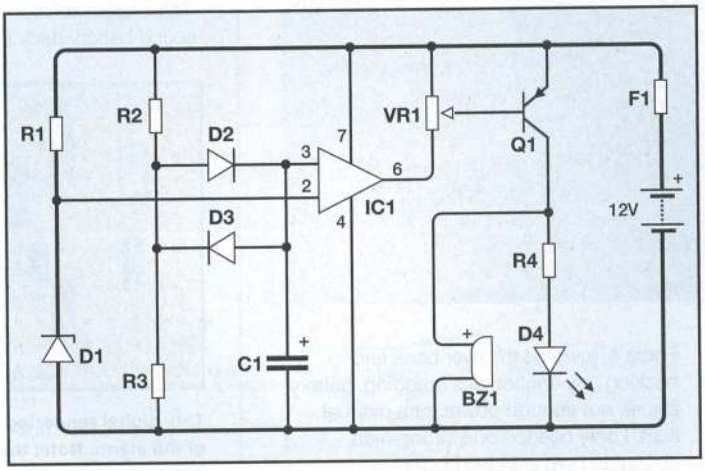
Basic version



Enhanced version



Example:

Assume supply voltage (Vs) is 13.4V (full battery), the node R1/R2 voltage is 6.4V: [(10k/(10k+11k)) x 13.4V].

Due to the forward voltage drop of D2 (0.4V), the capacitor C1 charges only up to 6.0V.

When the supply voltage drops, C1 remains at first at 6V, as the charge cannot drain away.

Only when the node R1/R2 drops below 5.6V, then C1 will overcome the forward voltage of D3 (0.4V) and begin to discharge via R3 to 0 (–).

A small rise in Vs voltage will stop more discharge, but the alarm will stay 'on'.

A further rise, like starting the engine, will pass D2 and recharge capacitor C1 and only then will the alarm switch to 'off'.

Alarm

The alarm is triggered from pin 6 of the op-amp 741 (IC1), which is either saturated +, or saturated –; that is about 10.5V or 1.5V.

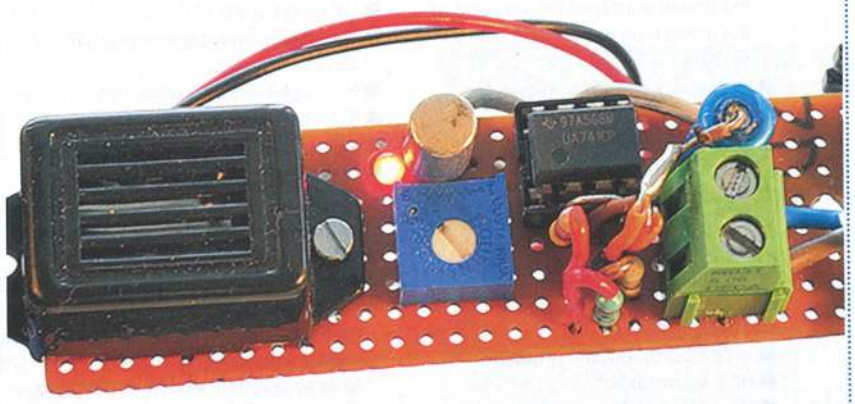
In the prototype, this 1.5V was enough to allow the buzzer to make a constant weak sound. So, instead, the output of pin 6 was fed to one side of a setting potentiometer VR1.

The setting slider adjusts the current from + Vs to the Base of PNP Transistor (Q1) from either a few μA to more than 200μA, which controls the current through the transistor Q1 to the load, from 0mA to 25mA.

That, in turn, sounds the buzzer (BZ1) and lights up the warning LED (D4).

When the main power is switched on, the unit will sound for ¼ second during the charging of C1, which proves it is working OK, but if the battery is lowish it will sound for seconds as a pre-warning!

When the onboard battery is switched off, the fast-dropping Vs voltage triggers the alarm for ¼ second.



Completed alarm showing its compact build. The LED will be placed separately in the electrical panel of the boat